Hybrid minithoracotomy approach for zero-fluoroscopy epicardial ablation of the arrhythmogenic substrate in Brugada syndrome

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Introduction

Since its first description in 1992,[1] Brugada syndrome (BrS) has claimed global attention as a remarkable cause of sudden cardiac death in young and otherwise healthy adults because of malignant ventricular tachyarrhythmias (mVT).[1,2]

Electrocardiographically, BrS type 1 is characterized by the presence of coved-type ST-segment elevation followed by a negative T wave in the right precordial leads. The anterior right ventricular outflow tract (RVOT) of BrS patients is characterized by low voltage (<1 mV), prolonged duration (>120 ms), and fractionated late potentials (beyond the QRS complex).[3] BrS abnormal electrograms (EGMs) are related to the electrical substrate at the basis of the electrocardiogram (ECG) pattern and the predisposition to develop fatal ventricular arrhythmias.[3] Currently, an implantable cardioverter-defibrillator (ICD) is still the mainstay of treatment for BrS,[2] but unfortunately it is not rare that patients experience recurrent ICD shocks with impaired quality of life and relevant psychological sequelae. For this reason, through the years several studies reported successful epicardial radiofrequency catheter ablation (RFCA) of the arrhythmogenic substrate harboring the anterior RVOT, resulting in normalization of the BrS ECG pattern and prevention of mVT.[3–6]

Given the above, we present a case of a patient affected by BrS and recurrent mVT who underwent successful epicardial ablation of the arrhythmogenic substrate by using a hybrid minithoracotomy approach.

KEY TEACHING POINTS

- Epicardial radiofrequency catheter ablation of the arrhythmogenic substrate located in the right ventricular outflow tract is a viable option for patients affected by Brugada syndrome (BrS) who experience recurrent malignant ventricular tachyarrhythmias.
- Pericardial puncture from the subxiphoid area is the most-described approach to gain pericardial access for mapping and ablation in the setting of BrS patients.
- Hybrid minithoracotomy approach via left periareolar incision is a feasible and safe technique for ablation of the arrhythmogenic substrate under direct vision, allowing for collection of myocardial biopsies and X-ray avoidance.

Case report

A 36-year-old woman with spontaneous type 1 BrS ECG pattern (Figure 1A) was referred to our center because of 3 episodes of ventricular fibrillation in the previous 2 months requiring the intervention of her subcutaneous ICD (Figure 1E) despite antiarrhythmic therapy with quinidine. Six months earlier, she received subcutaneous ICD implantation in primary prevention, given the presence of previous syncopal episodes and an electrophysiologic study positive for sustained ventricular tachycardia induction. Interestingly, the novel ECG marker named "dST-Tiso interval" was assessed and appeared to be 310 ms. We previously showed that the time interval between the onset of the coved ST-segment elevation and its termination at the level of the isoelectric line in V_1 and V_2 leads (dST-Tiso interval) is a powerful predictor of VA inducibility in drug-induced BrS type 1 pattern.[7]

KEYWORDS Ajmaline test; Brugada syndrome; Epicardial ablation; Long fractionated bipolar electrograms; Minithoracotomy; Zero-fluoroscopy

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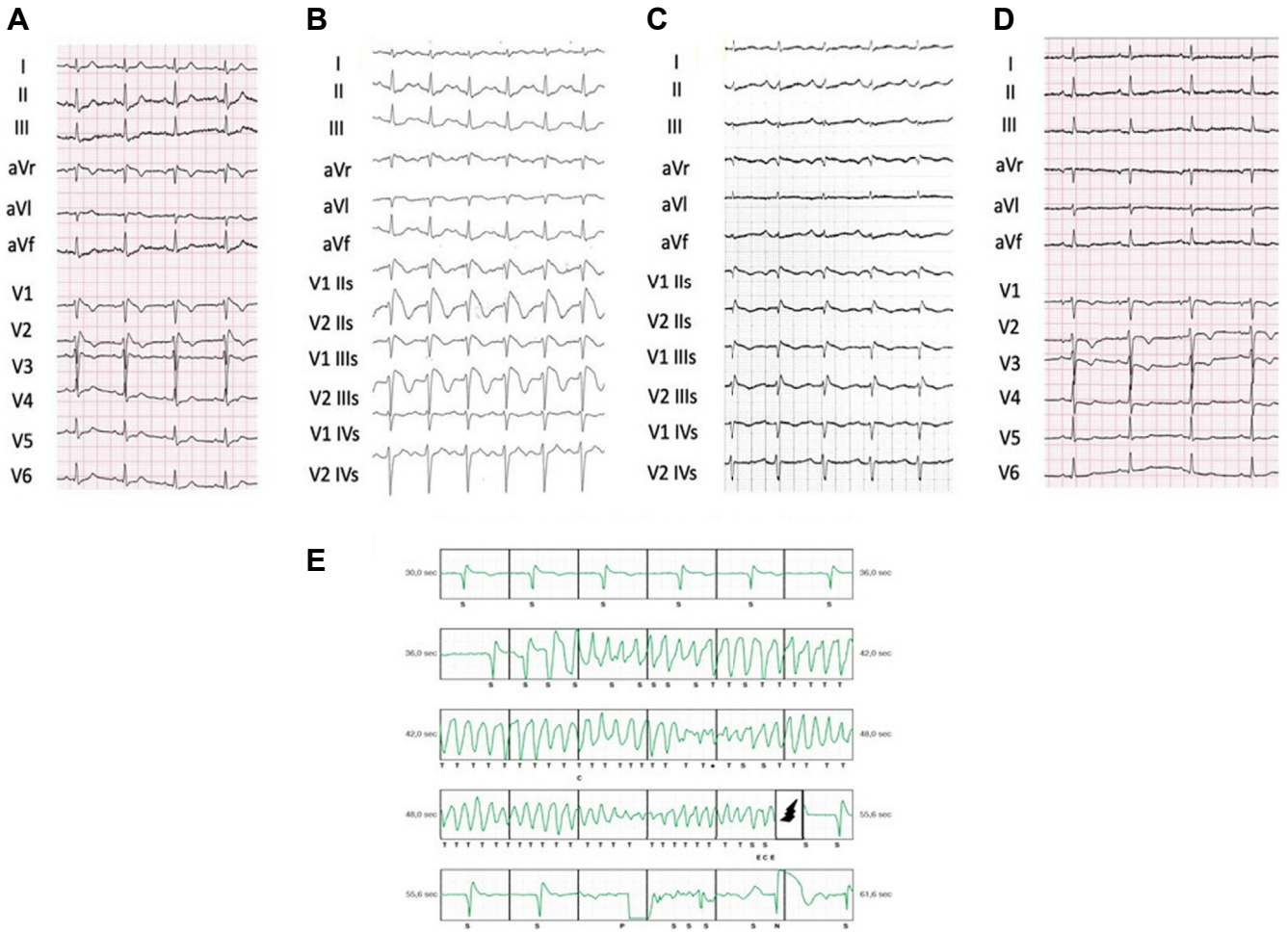

Figure 1 **A:** Electrocardiogram (ECG) of the patient with spontaneous type 1 Brugada syndrome (BrS) pattern. **B, C:** ECG during ajmaline administration at the time of the procedure, before (**B**) and after (**C**) the ablation of the epicardial pathologic substrate. **D:** ECG of the patient 1 month after ablation, without spontaneous type 1 BrS ECG pattern. (IIs-IIIs-IVs indicate position of chest electrodes during ajmaline infusion; II-III-IV, intercostal space]. **E:** Episode of appropriate subcutaneous implantable cardioverter-defibrillator shock delivered during ventricular fibrillation.

Transthoracic echocardiography and cardiac magnetic resonance were normal with no areas of late gadolinium enhancement detected. The patient was therefore scheduled for RFCA of the arrhythmogenic substrate by using EnSite Precision 3D mapping system (Abbott, Chicago, IL). After informed consent was obtained, the procedure was performed in a hybrid surgical room, under general anesthesia and invasive arterial pressure monitoring. An EZ-Blocker (Teleflex

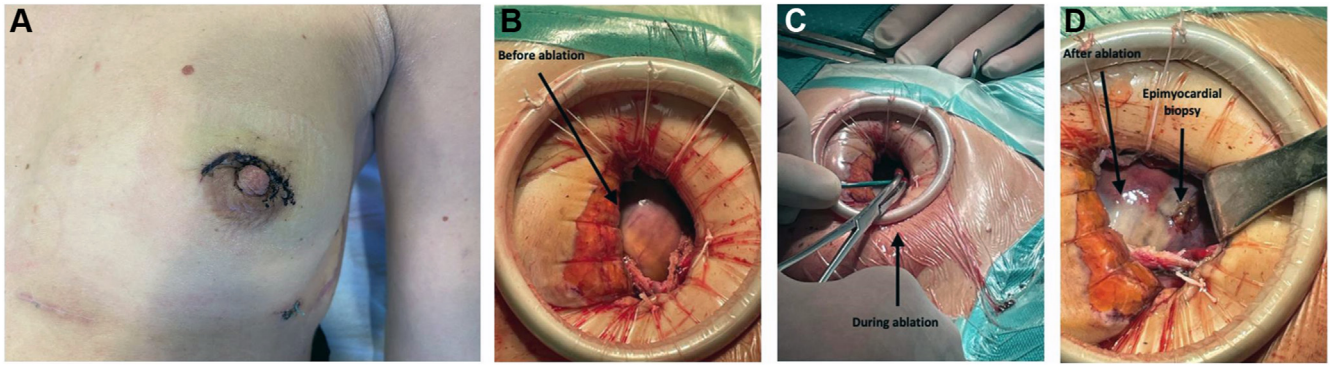

Figure 2 **A:** Left periareolar incision used to gain epicardial access. Noteworthy is the small dimension of the surgical incision and the good aesthetic result. **B–D:** The mini-thoracotomy window over right ventricle and right ventricular outflow tract anterior wall, before (**B**), during (**C**), and after ablation (**D**). As shown by panel C, the ablation catheter can be held with an atraumatic sawtell forceps fitted with silicon caps. In panel D the site of epimyocardial biopsy (collected before ablation) is also visible.

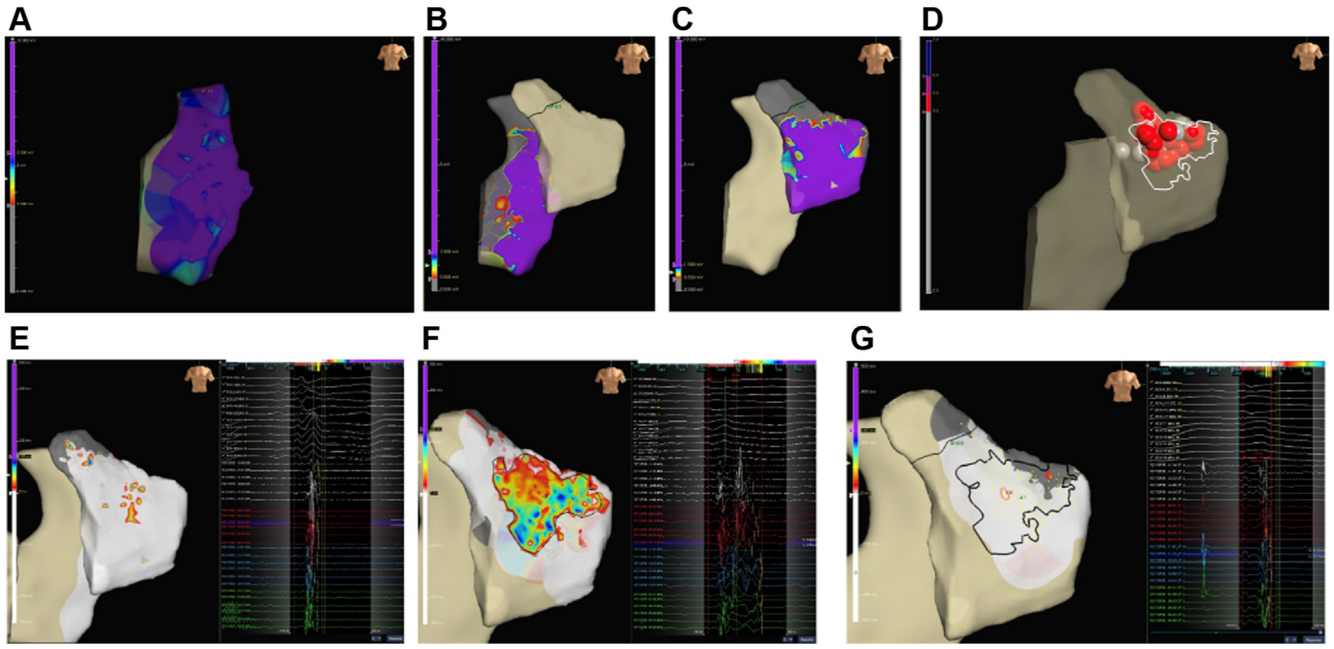

Figure 3 **A:** Normal unipolar voltage maps of right ventricular outflow tract (RVOT) endocardium. **B, C:** Normal bipolar voltage maps of RVOT endocardium and epicardium with their respective voltage cut-offs for normal/abnormal electrograms. **D:** Ablated area. **E, F:** RVOT epicardial late-potential maps before (**E**) and after (**F**) ajmaline infusion. It is noted that the RVOT epicardium does not display abnormal potentials (*white color* = normal potentials) apart from only few small islands of late potentials (*colored areas*). After ajmaline administration a 4.1 cm^2 area of epicardial RVOT late potentials has been unmasked and targeted for ablation. **G:** The result of epicardial radiofrequency catheter ablation, which completely abolished late potentials in the previously outlined RVOT area.

Inc, Morrisville, NC) endobronchial tube was used for selective lung ventilation.

Pericardial access was achieved via left anterior minithoracotomy requiring the patient to lie in a supine position. Cefazolin 2 grams intravenously was administered 60 minutes before the surgical incision and no anti-inflammatory or steroid therapy was administered in the days following the procedure. Firstly, a 5- to 6-cm-long skin incision was conducted along the upper edge of the areola, overlying the third left intercostal space (Figure 2A). Particular attention was then paid to prevent any damage to the mammary gland: after cutting of the subcutis, the gland was gently separated from the surrounding adipose tissue and dislocated downwards. By not using rib retractors but only soft silicone tissue retractors, the glandular structure could be completely spared.

After dissection of the external and internal intercostal muscles, discontinuation of lung ventilation was applied to displace the same lung with a tissue retractor, allowing the pericardial space to be visualized and entered over the right ventricle (RV) (Figure 2B).

During the refinement of the minithoracotomy, 2 right femoral venous accesses were obtained under echo guidance by a second independent operator. An Advisor HD Grid multipolar mapping catheter (Abbott, Chicago, IL) was used to create a high-density bipolar map of the RV and RVOT endocardium during sinus rhythm and a quadripolar diagnostic catheter was advanced up to the RV apex. Endocardial bipolar and unipolar electrograms, collected in a color-coded map with standard cut-offs (0.5–1.5 mV for bipolar and 3.5–5.5 mV for unipolar maps) revealed healthy RVOT endocardial and epicardial tissues (Figure 3A and 3B).

Following the endocardial map, the multipolar mapping catheter was placed on the epicardium through the minithoracotomy access. The surgical open space gives a direct view of the RV anterior wall, allowing the operator to move the catheter by holding it with the fingers or a sawtell forceps, approximately 4–5 centimeters from the tip. In this way, by dragging the mapping catheter during sinus rhythm, voltage and potential duration bipolar maps of the anterior epicardial RVOT and RV were created by automatic software annotation and manual confirmation (Figure 3C).

Potential duration time was defined in the bipolar signals as the time interval between the earliest activation time of any electrogram (activation-start) and the latest activation time of any electrogram (activation-end). Substrate mapping was carried out using the standard cut-off values (0.5–1 mV) to identify epicardial low-voltage areas.

The RV and RVOT anterior surfaces were mapped under baseline conditions, after ajmaline infusion (1 mg/kg in 5 minutes) and washout to identify the BrS epicardial substrate. Prior to ajmaline infusion, only few and very small islands of fractionated late potentials were detected in the anterior RVOT (Figure 3E). Ajmaline administration led to the appearance of type 1 BrS ECG-pattern (Figure 1B) and unmasked a 4.1 cm^2 area of abnormal EGMs located in the anterior RVOT surface (Figure 3F). Before ablation, an epimyocardial sample was collected from this region (Figure 2D) with the aim to discover the presence of structural cytological and histological alterations consistent with

cardiomyopathy; no significant abnormalities were seen. The biopsy samples were obtained under direct control and with dedicated bioptomes as Scholten biopsy forceps (Scholten Surgical Instruments, Lodi, CA) to minimize the bleeding risk.

All the pathologic EGMs inside the area were tagged to be targeted for RFCA delivery with a 3.5-mm-tip irrigated ablation catheter with contact force sensor (TactiCath; Abbott). The ablation catheter was held in place and moved on the epicardial surface by fingers or a sawtell forceps if needed (Figure 2C). Point-by-point ablation was performed in a temperature-controlled mode (max 43°C) with power limited to 35 W, until reaching a lesion index (LSI) of 5. Default power was set to 30 W and raised to 35 W only when impedance was over 120 Ω to reach the LSI target. Thirty RF ablations were delivered to completely ablate the fractionated late potentials previously tagged (Figure 3D and 3G).

After ablation, a second ajmaline administration did not induce type 1 BrS ECG pattern (Figure 1C). The epicardial remapping during the second infusion showed abolition of all abnormal ventricular potentials. Lastly, a final programmed ventricular stimulation protocol resulted in no inducibility of any ventricular arrhythmia.

The patient was discharged 5 days after the procedure without complications. Despite the limitation of a short-term follow-up of only 3 months, the beneficial effects of the ablation over this period were demonstrated by the disappearance of the spontaneous BrS type 1 ECG pattern (Figure 1D) and the absence of ventricular fibrillation recurrences.

Discussion

Since its first description in 2011,[3] both percutaneous[3,4] and thoracoscopic[8] approaches for BrS epicardial ablation have been reported. Despite encouraging outcomes and good safety profile, proven evidence of superiority of one technique over the other is still lacking. To the best of our knowledge, this is the first description of a hybrid minithoracotomy approach for zero-fluoroscopy ablation of the epicardial substrate in BrS, thought and realized with the aim to combine both electrophysiological and surgical skills in a hybrid fashion to overcome their respective limitations. Li and colleagues[9] already reported a similar safety profile, procedure duration, and long-term outcomes with a trend to lower procedural failures of surgical epicardial access through anterior or lateral thoracotomy for VT ablation, compared to those of a matched percutaneous access control group. Although the same study reports a limited epicardial explorable area with surgical approach, for BrS patients, in which the pathologic substrate is mostly clustered to the anterior RVOT, with possible extension along the RV anterior wall, the minithoracotomy approach may lead to several advantages. Firstly, the surgical access over the RV-RVOT anterior wall enables the operator to have a direct sight both on the areas to be ablated and on the structures, such as coronary arteries and their branches, that absolutely must be spared from ablation. Secondly, the hybrid approach gives the chance to easily collect epimyocardial biopsies in healthy and pathologic tissues. Thirdly, gripping the catheter close to the tip (by fingers or a sawtell forceps) enables better control of catheter contact, stability, and lesion growth during RFCA, leading to wider and more homogeneous lesions, less edema, and shorter procedural time. In our case, we performed a point-by-point ablation instead of dragging the catheter to obtain a more homogeneous lesion depth. As described by Themistoclakis and colleagues[10] in a porcine model, target LSI of 5 led to a lesion of 7.3 ± 0.8 mm in width and 4.7 ± 0.6 mm in depth. This setup allows reaching transmural lesions in the anterior RVOT, where tissue thickness ranges from 2 to 5 mm.[11] Another advantage of using a hybrid thoracotomy approach is the possibility to perform the whole procedure without X-ray exposure. Most procedures requiring catheterization entail radiation doses at the very least equal to that of a chest computed tomography (about 7–15 mSv),[12] and both stochastic (such as carcinogenesis) and deterministic effects (such as skin injury) should be considered among the possible risks for operators and patients (especially relatively young ones, as BrS patients). Lastly, the surgical minithoracotomy approach brings the chance to directly visualize the areas of interest, leading to a faster and easier management of complications, thus increasing the effectiveness of the procedure with a minimally invasive and aesthetically very acceptable approach for the patient.

Conclusion

Hybrid left anterior minithoracotomy approach for epicardial RVOT ablation is a novel and feasible technique to identify and eliminate the pathologic substrate areas in BrS patients, leading to only limited skin scars over the periareolar area. The approach allows the operator to have a direct vision of the areas to be mapped and ablated, collect biopsy samples, and avoid X-ray exposure.

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